

**DO EMOTIONAL DISTRACTOR PICTURES
SUPPRESS SEMANTIC PROCESSING
OF TARGET PICTURES?**

by

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ABSTRACT

Emotionally charged stimuli swiftly grab our attention even when we are deeply engrossed in other activities. This is readily apparent in a laboratory phenomenon known as “emotion induced blindness” or EIB. EIB occurs when people search a rapidly presented (RSVP) stream of scene pictures for a target picture, for example, a picture outlined in red. These targets become virtually undetectable when an irrelevant distractor picture containing negative emotional content precedes the target picture by about two tenths of a second. Longer intervals between the distractor and target restore detection to normal levels. What causes this brief period of blindness? According to one theory, the emotional distractor doesn’t affect the perceptual or semantic processing of the target but only interferes with *late* processes responsible for awareness, similar to other observed attention capturing phenomena. A competing theory holds that emotional pictures are special and suppress *early* perceptual processing of the target. The late-interference theory predicts that people should have full “knowledge” about the meaning of the target picture even when they are unaware of it, while the early-interference theory predicts that both perceptual and semantic information about the target is suppressed. These predictions were tested using EEG to measure the electrical activity of the brain. A brain response known as the N400 is smaller when two sequentially presented pictures are semantically related (for example, doctor-nurse) than when they are unrelated (such as clock-nurse).

According to the late-processing theory, the N400 should depend on the semantic relatedness of the target picture even when it cannot be reported. In contrast, the early-interference theory predicts no effect of this semantic relationship because EIB abolishes the perceptual and semantic processing of the target. Subjects were asked to view an RSVP stream and decide whether or not a “prime” picture outlined in red was related to a “test” picture at the end of the stream. The prime picture was preceded by a negative, neutral, or baseline distractor picture. N400s elicited by the test picture were completely suppressed during incorrect trials, regardless of distractor condition. I conclude that semantic priming, as measured with the N400, critically depends on awareness of the prime picture.

Chapter 1

INTRODUCTION

1.1 Emotion Induced Blindness

Emotional stimuli readily capture and hold our attention, sometimes at the cost of missing other important information. Whether the stimulus is extremely positive, negative, or surprising, this capture effect often overpowers other more relevant stimuli. For example, a person driving along a highway may be distracted by an accident scene alongside the road, and fail to notice brake lights from a stopping car in front of them. Although the accident scene may be irrelevant to the person's driving task, it captures attention and interferes with the driver's awareness of the task-relevant brake lights. This impaired awareness of relevant information due to an irrelevant emotional distractor is called Emotion Induced Blindness (EIB).

Most et al. (2005) were the first to study this phenomenon in the laboratory. Participants viewed a sequence of 17 pictures of various outdoor and cityscape scenes presented in a single location at the rate of 10 pictures per second (Rapid Serial Visual Presentation or RSVP). The participant had to search the picture stream for a target picture, which was identical to the background scenes but rotated 90 deg. to the left or right. In addition, an irrelevant picture could appear in the stream as well and participants were instructed to ignore it. The irrelevant picture could be an *emotional*

distractor consisting of threatening animals, dangerous insects, bloody faces, etc., or it could be a *neutral* distractor which also contained people and animals but in a non-emotional context (e.g. a dog). In the *baseline* control condition, the distractor was simply another background picture; in other words, a distractor picture did not appear in the sequence.

Most et al. found that the irrelevant emotional distractor severely impaired performance when the target appeared two pictures after the distractor (lag 2). This interference effect disappeared when the lag was extended to 8 pictures. The neutral distractor picture produced a much smaller effect, suggesting that much of the interference effect associated with the emotional distractor could be attributed to its emotional content rather than physical salience differences between the distractors and the background pictures. These results suggest that stimuli with emotional content capture attention, even when they are irrelevant to the observer's primary task.

This attentional bias has also been found to occur with verbal stimuli such as written words. Arnell et al. (2004, 2007) and Mathewson et al. (2008) performed experiments similar to Most et al. (2005), but substituted printed words for the picture stimuli. Emotionally arousing taboo distractor words impaired participants' ability to detect colored target words appearing in a background stream of black neutral words. These studies also found a positive correlation between arousal ratings of the distractor words and the probability of missing a following target. Emotionally arousing erotic stimuli have also been shown to interfere with target detection, despite strong monetary incentives to ignore them (Most et al., 2007). Arnell et al. (2007)

demonstrated that even subjecting participants to prior exposure of the emotionally arousing words used in the experiment did not reduce their effects. These studies using words as stimuli further support the notion that emotional arousal and not physical salience is responsible for the attentional interference effect because there are not any reliable physical features that discriminate between the various categories of words.

Studies conducted using patients with post-traumatic-stress-disorder provide additional support for the claim that attentional interference is related to emotional arousal rather than physical salience. Ehlers and Clark (2000) noted that incidental neutral stimuli that accompany traumatic events are stored as implicit memories that are activated when these stimuli are encountered in the future. These stimuli have the ability to automatically capture attention and reinstate the negative emotions associated with the traumatic event. For example, a patient involved in an automobile accident was briefly blinded by the headlights of the oncoming car. He later experienced strong sensations of fear when observing an area of bright sunlight on his lawn. Thus strong implicit memories associated with trauma-related stimuli are accompanied by attentional biases towards these stimuli, which help maintain the disorder by reactivating the memories of the original trauma. A recent study by Olatunji et al. (2013) used combat images to show that EIB effects in response to combat images were larger for combat-exposed veterans with PTSD compared to those without PTSD and healthy nonveterans. However all groups showed a similar EIB effect when shown non-war related emotional and neutral stimuli, indicating that

attentional biases to emotional stimuli rely on emotional content itself and not physical salience.

The precise mechanisms responsible for emotion-induced-blindness are still under debate (McHugo et al., 2013). Some investigators suggest that emotional stimuli capture attention in a fundamentally different way than neutral stimuli, which may capture attention by virtue of their physical salience. For example, emotional stimuli may activate a fast, specialized subcortical pathway involving the amygdala that can trigger rapid attentional capture. Non-emotional stimuli would have to capture attention using a slower pathway centered on neocortical mechanisms. These distinct mechanisms predict important differences in timing and other properties of attention capture by emotional and non-emotional stimuli. In order to evaluate these various theoretical proposals, first I review research on attention capture by non-emotional stimuli in a paradigm very similar to the one used to study EIB.

1.2 Attentional Interference in the Attentional Blink Paradigm

EIB bears at least a surface resemblance to a phenomenon known as the attentional blink (AB). Raymond et al. (1992) discovered the attentional blink after investigating previous work that demonstrated that difficulty is higher for dual tasks than single target tasks. They used an RSVP task to examine the effects of temporal spacing between two targets. The background stimuli were black letters. Participants had to report the identity of the first target (T1), which was a white letter, while

attempting to detect the appearance of a following target (T2), which was a black “X”. The time interval between the two targets varied, much like the time interval between the emotional distractor and the target in the EIB paradigm. They found that detection of T2 was severely impaired when it occurred two positions (200 milliseconds) after T1 (lag 2) but was fully recovered by lag 8, similar to what is observed in EIB. The term “attentional blink” refers to the 200-500 millisecond period of time following T1 when T2 is “blinked” from awareness and is unreportable. The duration of the AB thereby provides a measure the attention system’s temporal capacity limits (Dux and Marois, 2009). The emotional blink essentially tests the same temporal limits, but overloads the attentional system with a task-irrelevant emotional stimulus as opposed to the task-relevant but emotionally neutral first target used in the attentional blink.

Notice that during the EIB a *task-irrelevant* distractor impairs awareness of a subsequent target, while during the attentional blink a *task-relevant* emotionally neutral target impairs detection of a second target. Although both the attentional blink and emotional blink have similar behavioral effects in preventing a closely following target from reaching awareness, they appear to differ in initial attention capture. The involuntary attentional capture by the emotional distractor seems to be “bottom-up” and stimulus-driven, while capture by T1 in the AB appears to be top-down and goal-directed. However both processes interfere with goal-directed attention to the subsequent target (McHugo et al., 2013). Although the two types of stimuli may capture attention differently, the question remains as to whether or not they ultimately suppress the following target via the same underlying mechanism.

1.3 Two Opposing Theories of the Locus of Attention

1.3.1 Late Interference Theory

Late or Central interference theory is one of two opposing theories of how attention affects information processing. This theory also offers an explanation of the attentional blink (AB). It assumes that visual processing consists of two stages. The first stage consists of a rapid parallel identification of all incoming stimuli. During this unlimited capacity process all stimuli are identified and categorized, so their basic meaning is extracted. Following this stage there is a bottleneck which only allows one object at a time to gain access and become consolidated into working memory, which can only hold 3 or 4 objects (Zhang and Luck, 2008). Working memory is also thought to be closely related to conscious awareness. According to this school of thought, objects that fail to make it through the bottleneck also fail to reach awareness, even though they were identified and semantically processed in the earlier parallel stage. Stimuli that contain salient or important features are attended and enter the bottleneck leading to stage 2.

This theory explains the AB phenomenon as follows. During an RSVP stream targets and distractors enter stage 1 where they are identified and processed for meaning. Participants maintain a perceptual set for the feature that defines the first target (e.g., “red”), which means that only the target will trigger attention capture, and passage through the bottleneck into stage 2. While the first target occupies stage 2 and is being consolidated into working memory, the closely following second target enters

stage 1 where its identity and meaning are extracted. However, the second target must wait for the first target to finish stage 2 processing before it can enter stage 2 because it is a limited capacity system, and during this time it is vulnerable to masking by subsequent stimuli (Fig 1.1). Participants are then unable to report T2 because it was blocked from entering stage 2 by T1 and was never consolidated into working memory (Chun and Potter, 1995). At longer lags separating T1 and T2, T1 finishes stage 2 processing before T2 arrives, thereby eliminating the blink effect.

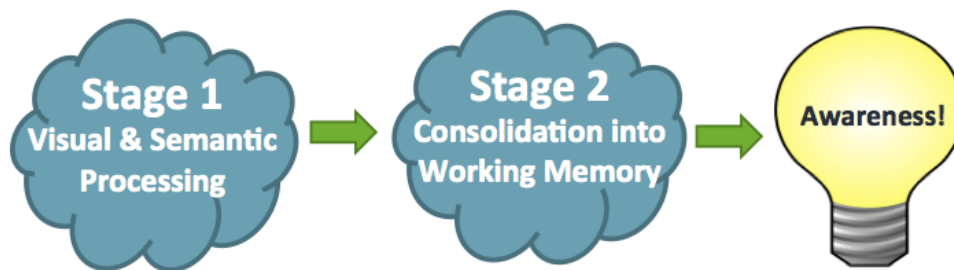


Figure 1.1: The two-stage model of the attentional blink, also called late or central interference theory. Previous research suggests that all incoming stimuli enter Stage 1, consisting of rapid parallel visual and semantic processing. If important features are detected, stimuli enter Stage 2 where they are processed one at a time by a limited capacity system allowing them to gain access to awareness. Notice that semantic processing occurs even when subjects are unaware of the target

Strong evidence supporting this explanation of the attentional blink includes a study performed by Vogel et al. (1998). They presented subjects with an attentional blink task while measuring event related brain potentials. They were able to show that T2s that are blinked still undergo semantic processing, indicative of stage 1

processing, but do not get consolidated into working memory. Additional electrophysiological evidence shows that T1 consolidation into working memory interferes with consolidation of T2 (Kranczioch et al., 2007; Vogel et al., 1998). These findings support central interference theory as the unreportable T2 was perceptually and semantically processed in stage 1 but was not consolidated into working memory during stage 2 processing.

The late interference theory may explain EIB in addition to the AB. All that is required is that the *task-irrelevant* emotional distractor in EIB act like the *task-relevant* first target in the attentional blink. In other words, one needs to assume that the emotional distractor automatically gains access to second stage processing and blocks access by a closely following target leaving that target vulnerable to masking by subsequent stimuli in stage 1. Kennedy et al. (2014) used electrophysiological measures in the EIB paradigm to show that task-irrelevant emotional pictures do act like a first target in the AB as they do gain access to stage 2 processing even though they are task irrelevant and should be ignored.

1.3.2 Early Interference Theory

Even though the Kennedy et al. results suggest that EIB and the AB can both be explained by the Late Interference Theory, their results don't exclude the possibility that emotional distractor may also suppress subsequent targets at stage 1 due to specialized mechanisms that are unique to emotional stimuli. This possibility is

consistent with the idea that emotional stimuli may be able to suppress perceptual processing of competing stimuli through a “subcortical pathway” centered on the amygdala which is rapidly activated by emotional stimuli from many sensory modalities (Zald, 2003). This possibility is supported by a recent study by Méndez-Bértolo et al. (2016) who recorded from single neurons in the human amygdala and found rapid onset of neural activity following the presentation of fearful faces but not neutral or happy faces. Interestingly, they found no early amygdala activation to emotionally arousing scenes. The amygdala projects to several cortical visual areas (Amaral et al., 2003) including V1, which is the earliest stage of visual processing in the cerebral cortex. This raises the possibility that emotionally salient stimuli rapidly activate the amygdala, causing quick activation of cortical areas controlling visual attention at early stages of the visual pathway. This early, preferential processing of emotional stimuli might also impair early perceptual processing of competing relevant stimuli that appear close in time and space to the emotional stimulus.

Some researchers remain skeptical about the role of a specialized subcortical pathway underlying attentional capture by emotional stimuli. Pessoa and colleagues (Pessoa and Adolphs, 2010) refer to this subcortical pathway as the “low road” in contrast to the “high road” represented by neocortical pathways. They suggest that a speed advantage for emotional stimuli due to rapid responses in the low road pathway is not convincing because *cortical* responses to non-emotional stimuli are also fast. For example, in the monkey brain, action potentials elicited by non-emotional stimuli reach a variety of cortical areas, including frontal cortex, in less than 80 milliseconds,

while responses from the amygdala are in the range of 100-200 milliseconds. More telling is the finding by Tsuchiya et al. (2009) that a patient without an amygdala showed the same fast responses to emotional stimuli observed in normal participants, suggesting that fast responses to emotional stimuli may not rely on the amygdala after all. Yet another study completed by McFayden et al. (2016) used MEG to show that a rapid subcortical amygdala route previously described as responding to face processing (Garvert et al. 2014) did not respond preferentially to emotion in faces.

On the other hand, some researchers claim that there is convincing evidence supporting a specialized mechanism by which emotional stimuli suppress competitors. Most and Wang (2011) investigated EIB in a display with two picture streams, one above and one below the fixation point. The distractor and target pictures could appear in the same or different streams with the distractor picture appearing two pictures before the target. Emotional distractors produced a larger blink when they appeared in the same stream as the target compared to the different stream condition. This isn't consistent with the central interference theory, which assumes that the first target disrupts a *central bottleneck* that no longer represents or cares about the spatial locations of the objects being processed. Most and Wang suggested that the emotional distractor picture, in addition to blocking the target from entering the stage 2 bottleneck, also competes for early perceptual resources during stage 1 processing (where location would matter), resulting in inhibition of *perceptual processing* of the following target (Wang et al. 2012). This implies that the blinked target in EIB, unlike

the AB case, would not undergo complete stage 1 identification and semantic processing.

A related study by Shaw et al. (2011) showed that emotion perception does not require “central” attentional resources. They presented participants with two faces (one happy and one sad) appearing on the left and right of fixation. They were given a target emotion such as “sad” and asked to determine the gender of the face displaying that emotion. They measured allocation of attention to the target face using the N2pc component of the ERP. The N2pc is a negative component with a latency of approximately 250 milliseconds appearing over occipital-temporal cortex contralateral to the visual field of the attended stimulus. This component provides a precise measure of the time at which attention is selectively allocated to a particular object. Participants also had to make a speeded discrimination response to an auditory tone presented at the same time as the faces. Previous research showed that selection of responses requires the involvement of the central bottleneck process and that when two tasks are simultaneously attempting to access it, one of the two tasks suffers a delay. In this case, however, they found that the latency of the N2pc reflecting attention capture by the target emotional face was unaffected by competition from the auditory task for central resources.

It appears that emotional stimuli can capture “perceptual attention” (reflected in the N2pc) without involvement of the bottleneck process. This supports the claim that at least some aspects of processing of *emotional* stimuli can proceed independently of central attention and this may not be the case for *non-emotional* stimuli. However, it should be noted that this latter claim, that non-emotional stimuli don’t show this pattern, is merely a conjecture because neither Wang and Most (2011)

nor Shaw et al. (2011) performed the same experiments with non-emotional capture stimuli.

1.4 Electroencephalography Recording (EEG) and Event Related Brain Potentials (ERP)

Neural mechanisms involved in EIB can also be studied using electroencephalography techniques, which measures electrical signals emanating from the brain using sensors placed on the scalp. The signals are amplified and then plotted as voltage over time, creating the electroencephalogram, or EEG. The EEG provides a useful measure of the global activity of the entire brain, such as changes in arousal but it is less useful in revealing activity associated with specific cognitive process such as attention or memory. However averaging the activity that is time-locked to the same event over many trials can increase the signal to noise ratio required to observe brain activity associated with particular sensory and cognitive processes. This averaged signal is known as an event-related potential or ERP (Luck, 2005). The ERP consists of a series of positive and negative deflections called ERP components, which are associated with synchronized activity in populations of neurons in various brain areas. This brain activity is ultimately related to underlying cognitive processes that make up mental activity. EIB and AB researchers have used this technique extensively because its precise temporal resolution enables the study of the extremely rapid processes that are involved in these paradigms.

Several well-known ERP components can be used to measure different stages of processing that stimuli proceed through on their journey from early perceptual processing to awareness. The N2 and P3b components are particularly useful in this regard. The N2 is a negative component appearing over occipital-temporal cortex with a latency of 200-300 milliseconds after onset of a visual stimulus, and is thought to reflect *attentional selection* of a target (Luck and Hillyard, 1994) for further processing. The P3b is a positive component that is broadly distributed over central and parietal cortex, and has a latency that can vary from 300 milliseconds to a second or more. The P3b is thought to reflect consolidation of a stimulus into working memory (Donchin & Coles, 1988). Kennedy et al. (2014) demonstrated that the N2 and P3b components that are normally elicited by a target picture were suppressed when the target was preceded by an emotional distractor. Vogel et al. (1998) and Sergent et al. (2005) found similar suppression of these components for missed targets in the AB paradigm. Thus it is well established that emotional distractors impair late stage processing of blinked targets, just as is the case in the AB, but the question remains as to whether or not ERP components reflecting earlier processes are suppressed as well. The current study utilizes the N400 ERP component to index semantic processing occurring in stage 1.

1.5 N400 and Semantic Processing

The N400 is a negative ERP with a broad scalp distribution over centro-parietal sites with a peak latency in the range of 400 milliseconds after stimulus onset (Kutas & Hillyard, 1982). It is more negative for concepts that are semantically unrelated than semantically related, and thus serves as a useful measure of semantic processing.

In order to investigate the role of sentence context on word recognition, Kutas and Hillyard (1980) recorded EEG while participants read sentences with either a congruent or an incongruent ending. An example of a sentence with a congruent ending is “I baked the cake in the oven” and an example of an incongruent sentence is “He hit the baseball with a stapler.” Incongruent endings elicited a negative waveform with a broad scalp distribution peaking around 400 milliseconds, which they called the “N400 component”. Importantly, they showed that this signal did not occur when the font size of the last word in each sentence was changed, suggesting that the N400 doesn’t simply reflect surprise, but is specific to the meaning and context of the sentence.

They suspected that the N400 was a marker of “reprocessing” of semantically incongruent stimuli. For congruent stimuli, a stimulus can “prime” other semantically related stimuli so that they are more readily processed. Expected information requires less processing in the primed brain, while unexpected information requires more processing, leading to a larger ERP component. This component was widely studied in the following years and was found to correlate with the semantic relatedness of items across many different kinds of tasks. Its amplitude was found to be sensitive to

semantic relatedness, being larger for more unexpected words. It was later revealed that N400 activity was present and affected by context for every word presented in a rapid serial visual presentation, thus indicating that every word in an RSVP stream was identified and semantically processed (see review by Kutas and Federmeier, 2011).

Nigam et al. (1992) were the first to show that picture stimuli also elicit an N400. Incongruent and congruent words and pictures presented at the end of sentences gave rise to an N400 that was similar in amplitude, topography, and latency. Ganis et al. (1996) used a similar paradigm in a study that compared N400s elicited by pictures or words using a larger number of sensors. Once again, both pictures and words elicited N400s but their denser recording array showed that words and pictures elicited N400s that differed slightly in their distribution over the scalp (their topography). They concluded that the N400s for words and pictures likely utilized neural systems that were partially overlapping and partially separate.

McPherson and Holcomb (1999) simplified these paradigms by removing all sentences and words, comparing N400 responses to pairs of pictures that were semantically related or unrelated. Participants were required to make relatedness judgments of two sequentially presented pictures separated by a blank screen. They found that unrelated pictures as well as words consistently elicited an N400-like response, indicating that this component reflects semantic relatedness regardless of presentation modality (pictures vs. words).

Additional studies examined whether the N400 reflected a controlled or automatic process. Controlled processes act in a top-down fashion and require attention, while automatic processes occur without awareness or cognitive control. Connolly et al. (1990) first tested the automaticity of N400 by having subjects listen to spoken sentences that contained congruent or incongruent endings. Subjects were asked to perform either a semantic or non-semantic task on the sentence. For example, during a semantic task they were asked whether or not the last word in the sentence belonged to a specific semantic category. A non-semantic, letter detection task required participants to judge whether or not a specific letter was present in the last word in the sentence. They found that the N400 was present even during the letter detection task, showing that the N400 generator is not dependent on goal-driven semantic processing.

Although it was shown that the N400 was not dependent on goal-driven processing, it could still be dependent on awareness of the stimuli. Stenberg et al. (2000) used visual masking to demonstrate that the N400 was elicited by pairs of semantically unrelated word stimuli that subjects were unable to report. A category was presented at the beginning of each block of trials followed by a series of briefly presented and masked target words. Participants had to identify the word and indicate whether it was related to the category. They found that the N400 was still elicited by words that couldn't be identified although it was attenuated compared to identified words. They concluded that the N400 does not depend on awareness.

Kuper and Heil (2009) presented participants with two letter strings separated by a short delay. The first string was always a word and people had to determine whether a particular letter was present in the word. This response was not timed and occurred at the end of the trial. The second string was either a word or a non-word string and participants had to make a speeded response indicating which it was. On trials in which both strings were words, they could be semantically related or unrelated. Previous research had shown that when the words were semantically related, the word/non-word response was faster than when they were unrelated, an effect known as semantic priming. It was also known that this effect disappeared when the interval between the words was very short, presumably because attention was still occupied with the search task being conducted on the first word even after the appearance of the second word. Kuper and Heil replicated this finding but found N400 priming effects even for intervals that were too short to allow semantic priming effects to appear in the reaction time measure. This supports the finding that the N400 is attenuated but not eliminated when attention is diverted from the eliciting stimulus, (as reviewed by Kutas and Federmeier, 2011). Hence the N400 can reflect semantic processing in the absence of attention.

1.5.1 AB and the N400

Additional evidence that semantic priming effects occur without controlled processing comes from experiments involving the attentional blink, which allow for

manipulation of awareness of target stimuli. Even word stimuli that are blinked by a preceding relevant target elicit a more negative N400 when they are semantically unrelated to that target. This shows that the word stimuli that are unreportable during the attentional blink are still processed for meaning

Shapiro et al. (1997) were the first to show that semantic priming of word targets could occur during the attentional blink period. They used three word targets (T1, T2, and T3), with T2 being presented during the blink interval following T1. Although the blinked T2s were unreportable, they still were identified and processed to the point where they could prime subsequent T3s and affect behavior (see also Martens et al., 2002). Vogel et al. (1998), reviewed earlier, found robust N400s to blinked target words that were semantically unrelated to a “context” word shown prior to each sequence. Importantly, this priming effect was the same magnitude regardless of whether participants could report the identity of the blinked target. Rolke et al. (2001) further tested this by recording ERPs in an attentional blink paradigm similar to Shapiro et al also using word stimuli. They also found similar N400s for both missed and reported primes, but no P300 for unreported primes, suggesting that semantic processing occurs for stimuli that fail to reach awareness. These results are consistent with predictions of the late interference theory.

1.6 1.6 The Current Study

The purpose of the present study is to determine whether the emotional blink can suppress semantic processing of a closely following prime picture. Semantic processing will be evaluated by measuring the N400 elicited by a clearly visible test picture presented after the prime picture. The test picture will be either semantically related or unrelated to the prime. The critical question is whether unrelated test pictures will elicit an N400 on those trials on which the prime picture was blinked and failed to reach awareness. If emotional pictures suppress early perceptual processing of pictures that follow in close temporal proximity, semantic processing should be eliminated when the prime picture fails to reach awareness. This is a very different outcome compared to what occurs in the AB in which words that are blinked and fail to reach awareness still show full-scale semantic priming. Different findings for EIB compared to AB would support the claim that emotional stimuli may produce interference with other stimuli using mechanisms that are distinct from those engaged by non-emotional stimuli.

The method is shown in Fig. 1.2. Participants searched an RSVP stream of scene pictures for a “prime picture” distinguished by a surrounding red frame. A *test picture* was presented 8 pictures later and was distinguished by having a duration four times longer than the other pictures in the stream. Following the end of the stream, participants had to indicate whether the test picture was semantically related or unrelated to the prime picture. They also indicated their confidence in this decision using a 3 point rating scale (“sure”, “not sure”, “guess”). A task-irrelevant distractor picture occurred two pictures prior to the prime. Distractors were one of three types:

emotional (negative), neutral, or baseline. The baseline distractor was a control picture of the same type as the background pictures in the stream.

There were two dependent variables. One was the accuracy on the semantic relatedness judgment, which should depend on how well subjects were able to perceive the prime picture. Prime perception should be highest in the baseline condition, intermediate with neutral distractors, and lowest in the emotional distractor condition. The second dependent variable was the amplitude of the N400 component elicited by the test picture as a function of the type of distractor and whether or not participants were correct on the semantic relatedness judgment. Of particular interest was whether the N400 would still be observed on trials in which the participant was incorrect on the behavioral judgment and whether this would differ between emotional and neutral distractors.

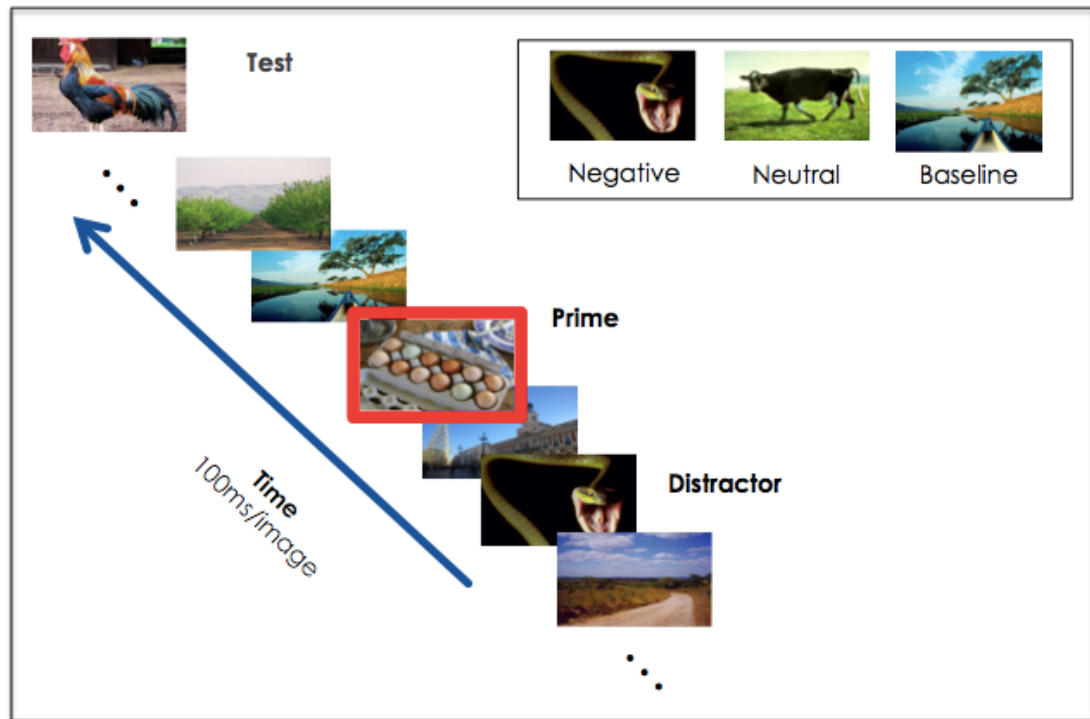


Figure 1.2: The experimental method: An RSVP stream of scene pictures with a negative distractor (snake) preceding the prime picture (outlined in red). The participant had to determine whether or not the prime picture was semantically related to the test picture near the end of the stream.

Note that I do not *directly* assess the reportability of the prime picture. Instead I use accuracy on the relatedness judgment given in response to the test picture as a proxy for awareness of the prime. The test picture is shown for a duration that is four times as long as the other pictures in the sequence and it occurs well outside of the suppression interval that follows the distractor picture. Therefore the test picture is highly visible and errors in semantic relatedness judgments can be attributed to difficulty in perceiving the prime picture.

Chapter 2

METHODS

2.1 Participants

Fifteen participants (12 women, 3 men; mean age: 20.5, age range: 18-22) were recruited through word of mouth and a classified ad at the University of Delaware. Each subject was compensated at a rate of \$10 per hour. All participants reported normal or corrected to normal vision. Each participant provided informed consent, and the study was approved by the University of Delaware Institutional Review Board.

2.2 Stimuli

The experiment took place in a dimly lit, electrically shielded, and acoustically isolated room. Displays were presented on a SAMSUNG 2233RZ 22" LCD Monitor (Wang and Nikolic, 2011) having 1,680 x 1,050 pixel resolution and a 60-Hz refresh rate. Stimuli were 320 x 240 pixel color photographs presented on a gray background at the center of the monitor. Participants used a chinrest to maintain a viewing distance of 70 cm, resulting in each picture subtending $6.4^{\circ} \times 4.8^{\circ}$ of visual angle. Experiments were controlled by a Dell 3.60 GHz computer. The experiment was

programmed with Python version 2.7 (Python Software Foundation, <http://www.python.org>; van Rossum, 1995) using PsychoPy software extensions (Peirce, 2007; Peirce, 2009). Eye movements were monitored with an Eyelink 1000 eye tracker using the Eyelink Toolbox extensions (SR Research, Ontario Canada). Eye position was sampled at 500-Hz. An eye movement was defined as three consecutive eye samples that were more than 1.4 degrees of visual angle (dva) from fixation.

There were 108 trials in each of 6 conditions (3 distractor types X semantically related/unrelated) for a total of 648 trials. Rest breaks were provided every 100 trials. Each trial consisted of 17 color images in the center of the screen against a gray background, with each picture replacing the previous one every 100 milliseconds.

The participant's task was to search for a prime picture, which was surrounded by a red rectangular frame and portrayed a scene containing a prominent object (Fig. 2 D). Participants then judges the relatedness of the prime to a "test" picture appearing at the end of the sequence whose duration was four times longer than the other pictures, (See Fig. 2 E and F).

Participants were given 10 practice trials at the beginning of the study. These sequences did not contain distractors and were not used in analyses. The prime picture was presented two positions (lag 2 or 200 ms) after the distractor picture, which appeared randomly at positions 2, 3, 4, or 5 in the stream. The test picture appeared 8 pictures after the prime and was either "related" or "unrelated" to the prime picture. Related and unrelated pairs occurred equally often in a random order. Distractor pictures were one of three types: emotionally arousing negative pictures of people or

animals, neutral pictures of people or animals, or “baseline” pictures (See Fig. 2 A, B, and C). The baseline distractor pictures were randomly selected from the set of background scene pictures. At the end of the trial participants were asked to judge whether the prime and test pictures were semantically related, and to rate their confidence on a 3-point scale (*Sure*, *Unsure*, or *Guess*).

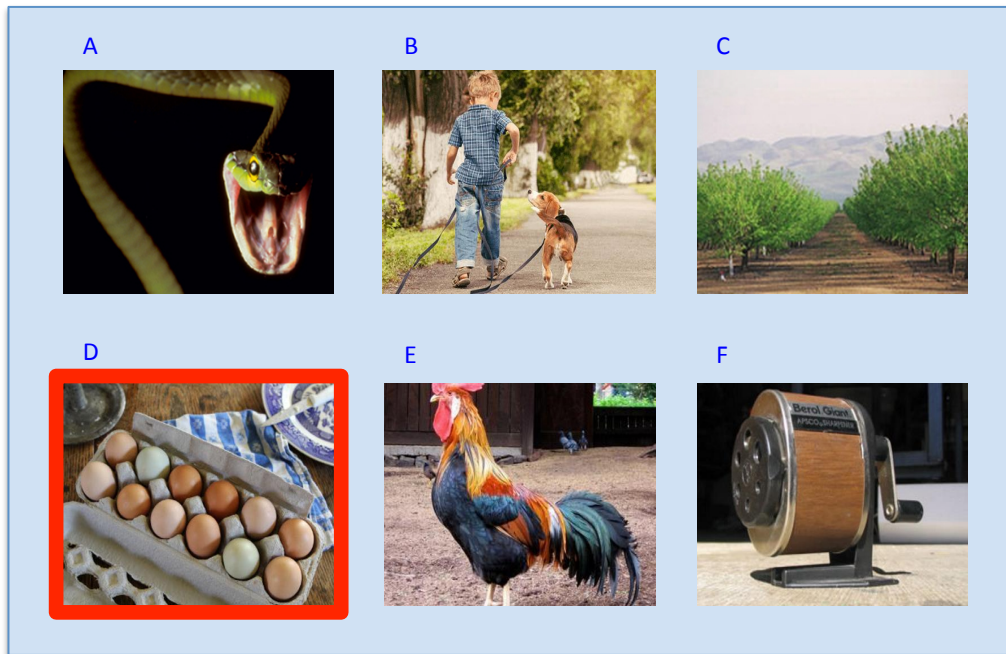


Figure 2: Examples of (A) a negative distractor, (B) a neutral distractor, (C) a baseline scene picture, (D) a prime picture, (E) a semantically related test picture, and (F) a semantically unrelated test picture.

648 pictures served as primes, and they were paired with a semantically related or unrelated test picture. Over participants, each test picture was preceded by a related or unrelated prime equally often. Background pictures were selected from a bank of 184 landscape and architectural photographs. There were 55 negative distractor pictures and an equal number of neutral distractors. Prior to beginning the experiment, participants were explicitly told that unpleasant pictures of people and animals would be present in the picture streams, and that they would never be the prime or test picture. They were reminded several times that they could

withdrawal from the experiment at any time and were shown examples of distractors to confirm that they were comfortable seeing the content. The International Affective Picture System (Lang et al., 1997) was the primary source of the negative and neutral distractor pictures. Additional negative and neutral images were taken from publicly available sources such as Google images. The pairs of related object pictures were based on the set of 800 pairs of related images described in Kovalenko et al. (2012). Their stimulus pool consists of pairs of single object pictures that were rated as being semantically related by a sample of 132 participants. I found comparable scene pictures in which these objects were prominent and appeared in the foreground (see examples in fig. 2). Some of these object pairs were replaced by others that were judged by the experimenters and lab members as being highly related.

2.3 Experimental Procedure

Participants were instructed not to blink or move their eyes during each trial. To ensure this, they viewed a red fixation point located at the center of the screen. Participants initiated each trial by pressing a mouse button to view the stream of stimuli. Next a black screen appeared for 1 second, and was followed by a responses screen depicting five answer choices. The choices were arranged in one group of two and another group of three. The first choices read either “related” or “unrelated” and corresponded to the semantic relationship between the prime and test picture. Upon selection of the first answer choice, participants were allowed to click on the second

group of answer choices, which corresponded with the confidence ratings. Participants were told to select “Sure” “Unsure” or “Guess” to indicate how confident they were in their semantic relatedness judgment. Once either answer was selected, they could not be changed. Incorrect responses as well as correct responses that were rated as guesses were categorized as incorrect. Feedback was provided in the form of a green “Correct” or a red “Incorrect” label, which appeared between the rows of buttons. Once the feedback screen was removed, the fixation point appeared in the center of the screen cueing the participant that the next trial was available.

The experimenter was given the opportunity at any time during the experiment to review each average accuracy levels and could change the duration of the prime picture if accuracy in the baseline distractor condition was too high (or above 95%,) or too low (below 70%). Participants were debriefed at the end of the experiment.

2.4 Electrophysiological Recording and Data Analysis

An Electrical Geodesics Inc. system (EGI; Eugene, OR) using a 129 channel Hydrocel Sensor Net was used to record a continuous electroencephalogram (EEG). As recommended by the manufacturer, individual electrode impedances were kept below 50-75 k Ω . Data was referenced online to the vertex, band-pass filtered from 0.01 to 80 Hz, and digitized at 200 Hz. EGI Net Station 4.1.2 software was used for subsequent offline processing. The data were low-pass filtered with a cutoff of 40 Hz and then segmented into epochs that began 200 milliseconds prior to the onset of

the distractor picture and ended 1,200 milliseconds after onset. If a channel's maximum voltage range exceeded 100 μV , it was marked as bad. Individual segments were rejected if more than 10 channels were marked as bad. Trials were also rejected if they contained blinks (threshold = 100 μV) or eye movements (threshold = 70 μV). For the remaining segments, bad channels were replaced by interpolating from surrounding channels. The segments were then averaged, re-referenced to the average reference, and baseline corrected using the 200-millisecond pre-stimulus interval.

2.5 Data Analysis Procedure

2.5.1 Event Related Brain Potential Analysis

Difference waves were used to isolate ERP components elicited by test pictures from the periodic ERP activity generated by the sequence of pictures (see Vogel et al., 1998). The N400 was isolated by subtracting the ERP elicited by the related picture from the ERP elicited by the unrelated picture.

The N400 was measured as the average activity in six contiguous sensors centered on Cz. This location is in good agreement with previous research on the N400 (Kutas and Federmeier, 2011). Component amplitude was measured as the average amplitude in a window extending from 350-450 milliseconds. N400 amplitude in the various conditions was analyzed with a repeated measures analysis of variance (ANOVA), which employed Greenhouse–Geisser corrections for violations of

sphericity. Significant main effects involving three levels of a factor (e.g., negative, neutral, and baseline distractors) were followed up with least significant difference (LSD) tests between each pair of means. This procedure does not involve a correction of the alpha level for multiple comparisons, because there is no inflation of family-wise error rates for the special case of three conditions, as long as post hoc tests are preceded by a significant main effect (Cardinal and Aitken, 2006).

Chapter 3

RESULTS

3.1 Behavioral Results

Figure 3.1 shows accuracy in categorizing the test picture as being semantically related or unrelated to the prime picture as a function of the type of distractor picture that preceded the prime. These data were analyzed using a two-factor (semantic judgment type: related vs. unrelated X distractor type: baseline, neutral, and negative) repeated measures ANOVA, which revealed significant main effects of distractor type ($F(2, 28) = 73.47, p < .001$) and judgment type ($F(1, 14) = 42.41, p < .001$). The main effect of judgment type reflects higher accuracy for related compared to unrelated trials. The main effect of distractor type reflects accuracy that was highest in the baseline condition, intermediate for neutral distractors, and lowest in the negative distractor condition. The ordering of accuracy across distractor type is consistent with previous EIB results,

In addition there was a significant interaction between these variables, $F(2, 28) = 17.43, p < .001$. This interaction was analyzed by computing the difference between related and unrelated conditions for each distractor type. These difference scores were entered into a one-way ANOVA using the factor of distractor type. The main effect was significant ($F(2, 28) = 17.43, p < .001$); same as the significant

interaction reported above. Post-hoc LSD tests showed that relatedness had a larger effect in the neutral condition than the negative ($p = .002$) and baseline ($p < .001$) conditions. However there was no significant difference between negative and baseline conditions ($p = .050$).

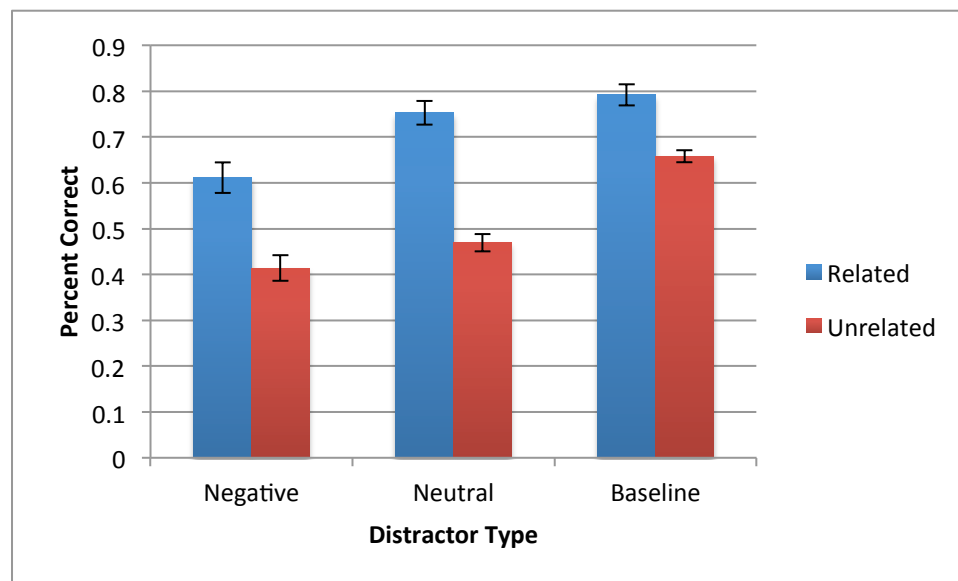


Figure 3.1: Behavioral results across all six conditions. Error bars show the standard error of the mean.

These results indicate that both distractor conditions impaired perception of the prime picture relative to the baseline distractor, with more impairment associated with the negative distractor. It might be surprising that neutral pictures produce interference, but they are physically salient in the context of the background scene pictures because they contain people and animals appearing in the foreground of the image. This salience causes them to capture attention and interfere with the perception

of closely following pictures. The greater suppression associated with the negative distractor suggests that emotional content of the picture and not just physical saliency can play a role in the suppression process. These results replicate previous findings using the emotion-induced blindness paradigm (Most et al., 2005; Kennedy et al., 2014).

Subjects were also more accurate on semantically related trials compared to unrelated trials. This seems puzzling because the test picture can't be the source of errors as it is presented for a long exposure duration that makes it quite visible. Instead, it appears that the greater accuracy for related vs. unrelated trials may be simply due to a strong bias to guess "related" when responding without any information. For example, when subjects used the confidence rating of "guess", they apparently really were guessing as their accuracy was approximately 54% collapsed across all three distractor conditions which is quite close to the chance performance level of 50%. When this is broken down by related vs. unrelated, participants were 73% correct in the related condition and only 29% in the unrelated condition. Notice that the 29% correct in the unrelated condition is well below chance (50%) showing that participants are guessing but they have a strong bias to guess "related". This is also true in the "not sure" category where accuracy rises to 61% with 77% correct on related trials and 34% on unrelated trials. The low performance in this rating category indicates that most of the responses are guesses, which strongly favor the "related" response. To fully evaluate the role of guessing in this paradigm to determine if there

are any relatedness effects over and above a guessing bias will require a detailed signal detection model of responding in this paradigm.

3.2 Electrophysiological Results

3.1.1 The N400 Component

Figure 3.2a shows a topolot of the N400 component, which appears as a broad negativity over anterior/central front sites peaking between 455 and 480 milliseconds after onset of the test picture. A repeated measures ANOVA with factors of distractor type (negative, neutral, and baseline) and accuracy (correct/incorrect), revealed a significant main effect of accuracy ($F(1, 14) = 36.2, p < .001$). There was no effect of distractor type ($F < 1$). This confirms what is apparent in figure 3.2: N400's of comparable amplitude are generated in all three distractor conditions when participants are correct. On incorrect trials, the N400 is absent for all three distractor conditions.

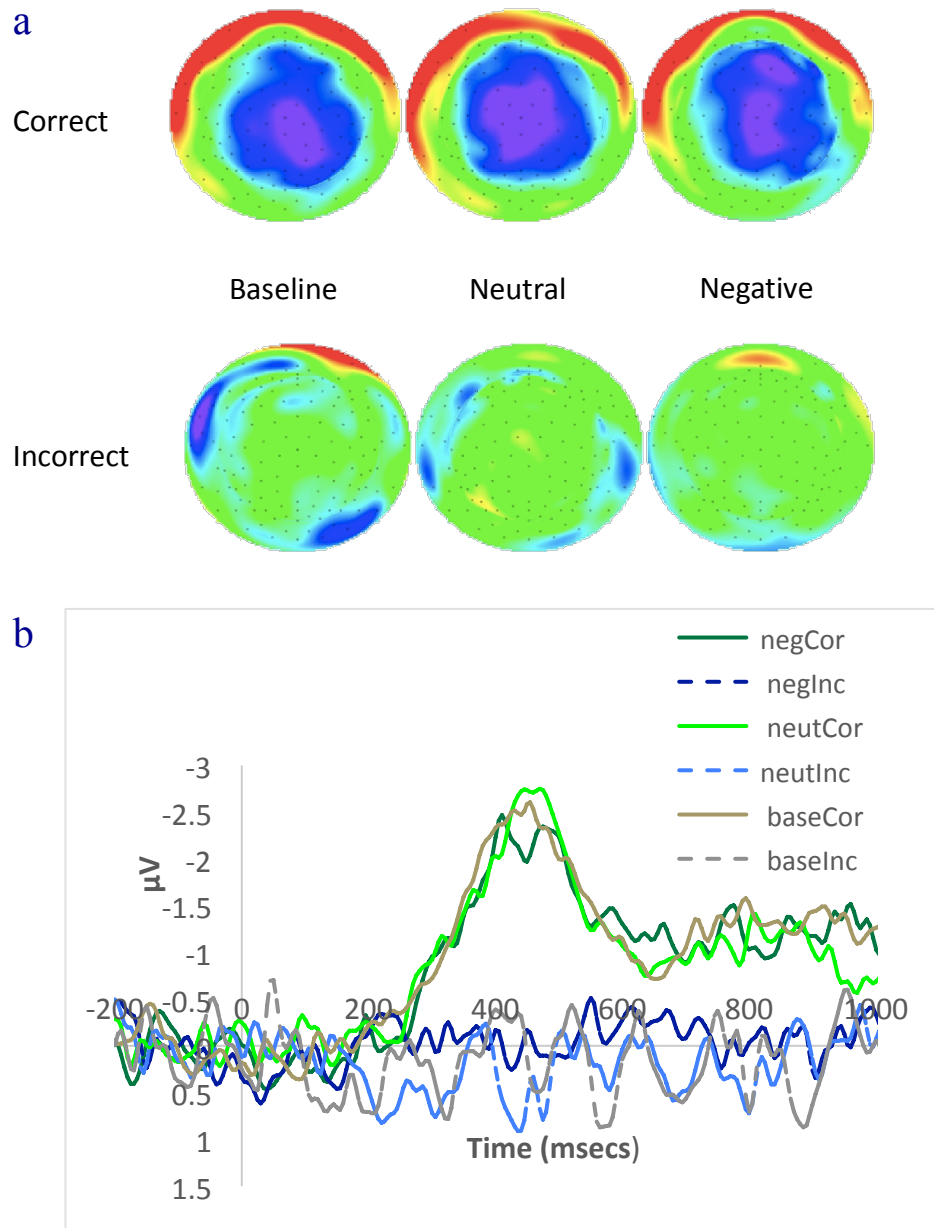


Figure 3.2: N400 (**a**) as a topoplot and (**b**) as an ERP waveform peaking at 455-485 milliseconds in response to test pictures for correct and incorrect trials across the three distractor type conditions (negative, neutral, and baseline).

Chapter 4

DISCUSSION

4.1 Behavioral Results

4.1.1 Distractor Type

Previous studies of emotion-induced blindness (EIB) have found that task-irrelevant, emotional distractor pictures impair awareness of closely following targets (Most et al., 2005; Kennedy et al., 2014), a result that is similar to what is observed for two closely spaced, task-relevant, emotionally neutral targets in the attentional blink (AB). Do these two similar patterns of results reflect the same underlying mechanisms or does EIB engage specialized mechanisms that are unique to emotional stimuli? Some researchers have suggested that emotional stimuli activate a fast-acting subcortical pathway involving the amygdala, which might result in rapid capture of attention potentially leading to suppression effects from emotional stimuli that occur earlier in the chain of processing than suppression observed in the AB.

Suppression effects in the AB are thought to occur late in processing, after perceptual and semantic processing has been completed but prior to awareness. This is reflected in intact semantic priming effects for blinked targets in the AB. If emotional pictures suppress early perceptual stages in target processing, priming should be suppressed as well. Early suppression effects by emotional pictures might be detected as an elimination of semantic priming for blinked targets following emotional but not

neutral distractors. I evaluated this possibility by measuring priming with the N400 component of the ERP, which is larger for semantically unrelated relative to related pairs of words or pictures.

Previous EIB studies show that emotional distractor pictures impair detection of targets occurring approximately 200 milliseconds later (Most et al., 2005; Kennedy et al., 2014). Our behavioral results agree and indicate that task performance was lowest in the negative distractor condition, somewhat impaired in the neutral distractor condition, and highest in the baseline condition. The negative and neutral distractors were similar in physical content as they were both pictures of people and animals, but differed in emotional content. This suggests that the negative content of the emotional distractor pictures impaired performance in a bottom-up, stimulus driven manner, and was able to capture attention although irrelevant to the task.

4.1.2 Relatedness

Semantic priming occurs when a second word is processed more rapidly or accurately when it is preceded by a semantically related word. This is thought to occur automatically and allows primed words to reach some level of activation more quickly (Neely, 1991). This was observed in a study by Davenport and Potter (2005) that used RSVP streams containing words that demonstrated a strong effect of priming on target identification in RSVP stream. During the first experiment, accuracy was higher when participants were asked to report two related words rather than unrelated words. In a

second experiment, they tested to see whether or not the priming effects observed were due to controlled processing. In this experiment, they asked participants to only report semantically related targets, reasoning that accuracy should improve from the first experiment (where target identification was the only task) if priming is controlled and not automatic. Accuracy was not significantly different in the two experiments, so they concluded that priming effects are automatic, not controlled.

A similar study performed by McKenna (2014) also attempted to use emotional distractor pictures to blink a target in a semantic judgment task. However, that study differed in that the prime was given at the beginning of the stream before the distractor, and the target was presented at lag 2 after an emotional distractor (Fig. 4.1). In this study subjects were also more accurate when targets were semantically related, and they suggested that this could be due to a “pop out” effect of related pictures. It is possible that the semantically related pictures “prime” the attentional system so that it more easily detects related pictures downstream.

This is further evidenced by McKenna (2014), as she found no emotion induced blindness effects, which appeared to be due to related pictures breaking through the emotional blink. She suggested that this could be due to strong semantic priming effects that prevent the target from being blocked by the emotional distractor.

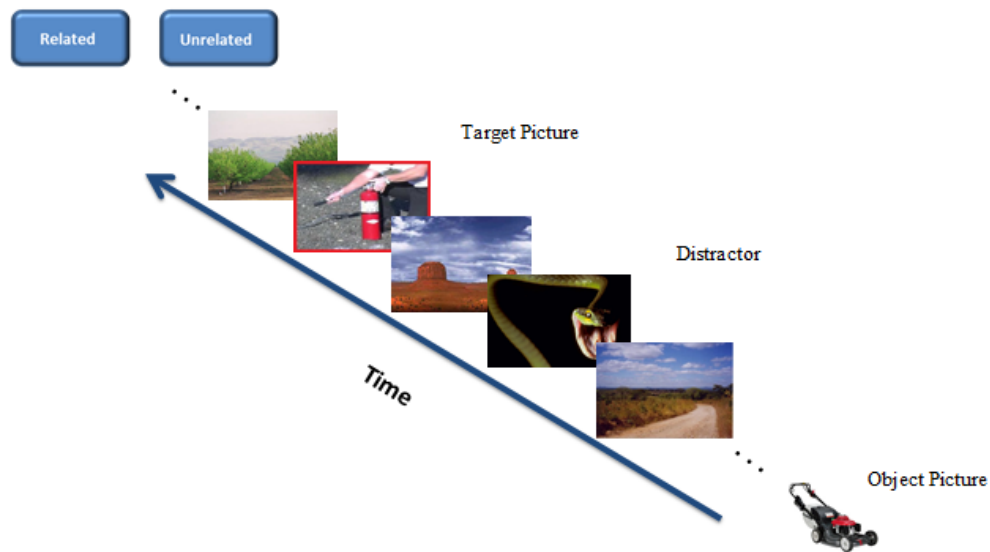


Figure 4.1: An illustration of McKenna 2014's task. "Target pictures were presented on a white background for 1500ms. The RSVP stream began after a 100ms blank with each picture presented for 83ms. A negative (shown here), neutral or baseline picture was presented. Two pictures later, a target picture with a red frame was presented. Once the stream ended, participants were asked whether the target picture was related or unrelated to the object picture and how confident they were about their decision."

This priming effect has also been found in other similar experiments using word stimuli. Stenberg et al. (2000), mentioned earlier for their finding of an attenuated N400 from masked targets, also observed this effect in a task involving semantic words pairs and a mask. Participants were more likely to correctly judge semantic matches when the stimuli pairs belonged to the same category, or were related, and less likely to be accurate when the stimuli were unrelated.

As mentioned earlier, the finding of an accuracy advantage in the present paradigm is somewhat puzzling because the test picture was presented well above threshold and therefore errors must have been due to failures to perceive the earlier

prime picture, which was presented for a short duration and preceded by attention-capturing distractors. How can the semantic relatedness of the test picture work backward in time to affect the perception of the prime? One possibility is that participants may often retain a partial impression of the prime picture and the presentation of a related test picture effectively narrows the possible interpretations of the test picture and allows it to be understood. In this case, semantic relatedness would be working to actually improve the information underlying the decision about relatedness.

A second possibility, mentioned in the results section, is that greater accuracy on related trials is simply due to a bias to respond “related” rather than “unrelated” when participants are forced to guess. The results section provided strong evidence supporting such a guessing bias. Another way to see this is to ask whether related trials were more likely to lead to high confidence ratings than unrelated trials. If semantic relatedness increased the likelihood of “perceiving” or correctly reinterpreting the prime picture, perhaps like the mechanism described above, one might expect that related trials would be more likely to induce the use of high confidence responses than unrelated trials. However, the probability of using the “sure” response was 0.56 for unrelated trials vs. 0.49 for related trials, which doesn’t support this possibility.

4.2 ERPs: The N400

In accordance with previous studies (McPherson and Holcomb, 1999), I observed a more negative N400 in conditions where target and test pictures were unrelated compared to conditions where the target and test were related. Therefore the

N400 observed in our study represented semantic processing of the test picture that had been primed by the target.

Perhaps the most surprising result was that an N400 was not observed for incorrect trials. This is in disagreement with several studies, which found that the N400 is either unaffected by awareness (Vogel et al., 1998) or is present in an attenuated form for unaware trials (Stenberg, 2000, reviewed by Kutas and Federmeier, 2011). However, many of these studies incorporated word stimuli, rather than pictures. Although the N400 represents semantic processing across stimulus modalities, it is thought that the N400 produced by picture and word stimuli are not identical but represent partially overlapping processes. This means that the semantic processing systems for pictures and words may be slightly different. For example, Davenport and Potter (2005) describe a priming system between words where the locus of priming occurs at the point of lexical identification. They theorize that word stimuli compete for attention resources that lead to lexical priming during stage 1 early processing. The target that is lexically processed then gains access to stage 2, where it blocks the competing stimulus from attention. As a result, they were able to show that semantic priming affects the lexical identification of a target, reasoning that this is evidence of early semantic processing during the AB period. However, pictures are not lexically identified, so their priming effects may operate under a different system. This pictorial processing system may involve different steps than the word processing system, and may explain the discrepancy in these findings.

Some have suggested that the systems responsible for semantic priming of pictures and words operate under two partially overlapping but separate systems. Barrett and Rugg (1990) performed an experiment with two pairs of word and picture

stimuli and measured ERPs to related and unrelated pairs. They found two components, a widely distributed N450 component responding to picture and word stimuli, and a more anterior N300 component that has not been observed using word stimuli. They concluded that it is likely that processing of pictures may utilize overlapping but different neural networks than word stimuli. Ganis et al. (1996) used sentences that ended with a terminal word or picture representing the same concept. They found that the N400 was slightly more anterior in response to pictures than words, again suggesting partially overlapping neural systems for semantic processing of words and pictures.

McPherson and Holcomb (1999) also found a more frontally distributed and earlier component in response to semantic picture pairs compared to words. The early component, called the N300, appeared to be picture specific and similar but separate from the later amodal component (N400). This early component was sensitive only to whether or not the pictures were related or unrelated, while the later component responded to the *degree* of relatedness between the pictures. However, the current study was only concerned with whether or not the target and test picture were related, but not the degree. It is possible that this pictorial system operates differently than the word system and does not automatically semantically process picture stimuli, but this remains unknown.

There are some examples of diminishment of the N400 in the absence of awareness of a stimulus. Kang et al. (2011) demonstrated that the N400 for word stimuli was absent on trials when the target was not reportable during interocular suppression, a finding that is similar to mine. A context word was given at the beginning of each trial, and the participant was instructed to look at two different

streams of stimuli. Mondrian patches that filled a square frame, which were used as visual masks during the interocular suppression, were presented for 700 milliseconds in one stream, while the target word appearing in the other stream after a 100 ms blank screen (See Fig. 4.2). The contrast or duration of the target word was changed so that it was either reportable or unreportable, and the N400 was absent for suppressed stimuli. Although somewhat different from the temporally sensitive attentional blink, this demonstrates the sensitivity of the N400 to awareness and supports that it is not completely automatic, operating differently under different circumstances.

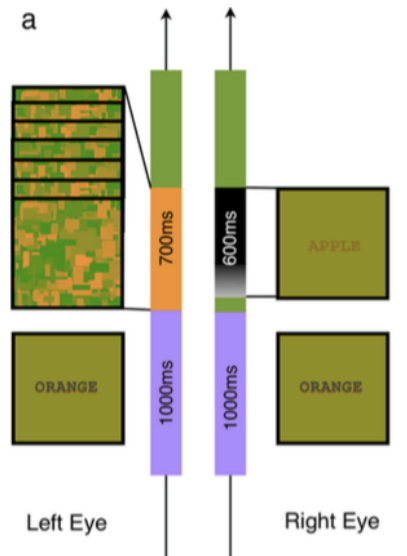


Figure 4.2: The method used by Kang et al. 2011. “Illustration of stimulus sequence of Experiment 2 (related-pair type of a suppression trial). Context word (ORANGE) is presented to both eyes for 1 s and the first Mondrian frame is presented to one eye immediately. Seven Mondrian frames are presented in sequence, one every 100 ms. The target word (APPLE) is presented the other eye after a 100 ms blank interval. The contrast of the target word was gradually increased for the first 300 ms and remained the same for another 300 ms. “

In a study similar to Vogel et al. (1998), Giesbrecht et al. (2007) tested the automaticity of the N400 using an attentional blink paradigm, and found complete suppression of the N400 under “high load” conditions. Each trial started with a context word presented for 1000 milliseconds, followed by T1 (arrows pointing either to the left or right), a mask, T2 (a word either related or unrelated to the context word), and another mask. Subjects were then asked the direction of the arrows and whether or not T2 was related to the context word. T1 was manipulated by the direction of the central arrow to the flankers, with low load occurring when the central arrow was in the same direction and high load occurring when the central arrow pointed in the opposite direction of the flankers (Fig. 4.3). In this experiment and a follow up experiment that accounted for possible potential confounds of spatial attention, Giesbrecht et al. (2007) found a complete suppression of the N400 to T2s when they were unreportable during the attentional blink period. They attribute their failure to replicate Vogel et al.’s results to the attentional load theory, which predicts that attention selects information at later stages of processing (post semantic processing) under low load conditions. Under high load conditions, this model predicts that attentional selection occurs at earlier perceptual processing, before semantic identification. They argue that Vogel’s paradigm operates under low load conditions, but semantic processing of blinked targets disappears under conditions with higher load. In the present study, some element about our task (perhaps something associated with the pictorial nature of our distractors) may have also operated under a high load condition, inhibiting semantic processing of the target. For example, the processing of the scene and object pictures with its many parts, depths, and colors may operate under a higher load than the processing of simple word stimuli consisting of letters on a blank background.

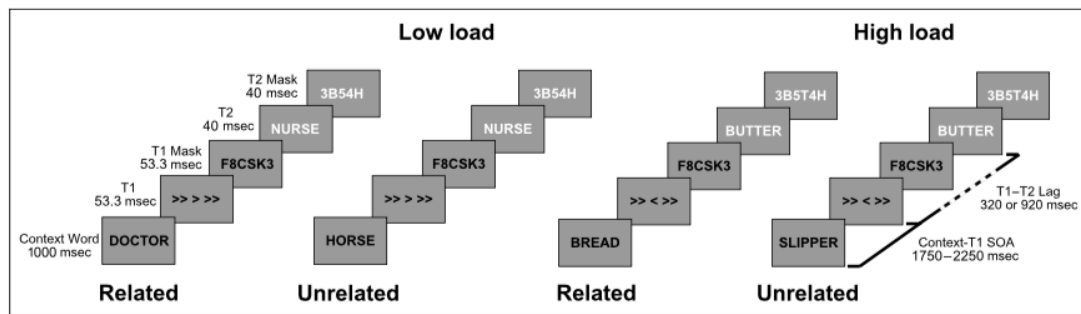


Figure 4.3: Geisbrecht et al. (2007) methods. “On the left are examples of T1-low load trials when the context word and T2 word were related and unrelated. On the right are examples of T1-high load trials when the context word and T2 word were related and unrelated. For complete details on the stimulus timing, see Methods. “

A growing body of evidence has also supported that the N400 for word stimuli represents a post lexical process requiring awareness and availability of attentional resources. In a similar study to Vogel et al. (1998), Batterink et al. (2010) revisited the question of semantic processing to missed word targets in an attentional blink paradigm. They presented a context word at the beginning of each trial, and asked participants to identify two targets in a stream of letters. T1 was a number, and T2 was a word that was either related or unrelated to the context word, and occurred either within or outside of the attentional blink period. Accuracy in determining semantic relatedness was low when T2 was present in the attentional blink period and high when it occurred outside of it. When results were analyzed separately for correct and incorrect trials during the attentional blink period, Batterink et al. found that the N400 was present for correct trials but not incorrect trials. This is similar to the finding presented here but is in contrast to Vogel’s findings, which indicated that the N400 was fully present even when subjects were incorrect. Batterink et al. suggest that this

can be attributed to differences in T1 attentional load, which may have been higher in their procedure than in Vogel's. They offer their lower accuracy in reporting T1 (86%) as evidence that their task was more difficult and higher in load than Vogel's, whose accuracy in T1 report was higher (93%). Overall accuracy was also low in the current study, as the baseline accuracy was low compared to previous studies (around 72%), and this may evidence a high attentional load for our stimuli.

The current study obtained results that are similar to those of Batterink et al. (2010), i.e., semantic priming, reflected in the N400, is completely absent for missed stimuli regardless of distractor condition. Thus, semantic priming only occurred when participants were aware of the prime. These results rule out the possibility of evaluating whether emotional stimuli result in suppression of targets at earlier processing stages than non-emotional stimuli used in the AB paradigm. The present results suggest that the late interference account of the AB may not be generally true. I found no evidence supporting the claim that interference in EIB is localized at late stages of processing that occur after semantic analysis. Instead it appeared that stimuli that do not make it into awareness are not processed semantically. This finding doesn't appear to be simply due to potential differences between pictures and words because Batterink et al. (2010) and Giesbrecht et al. (2007) reported similar findings for words. The reasons for these discrepancies between different studies aren't clear and will require additional research.

4.3 Future Studies

Many questions need to be answered regarding semantic processing and distractor interference. First and foremost, it remains to be determined whether or not different types of target stimuli occurring within the attentional blink period are

semantically processed. I have shown that missed picture stimuli in the EIB blink period do not undergo semantic processing, regardless of the emotional content of the distractors. The next step would be to determine if this is also true for word stimuli, and if emotional content affects word stimuli differently than other types of distractors and exhibit similar patterns to picture stimuli.

Another limitation that may be resolved in the future is the ability to observe ERP components directly linked to the target pictures that are being suppressed. In the current study, only ERPs to the test pictures at the end of the stream were observed. This is due to the fact that the distractor and target pictures occurred closely together in time. I was consequently unable to separate the overlapping components elicited by distractor and prime picture, because there was not a distractor-only condition. This was due to limitations in the amount of feasible trials, due to the fact that there were 6 conditions that needed to be evaluated (negative related, negative unrelated, neutral related, neutral unrelated, baseline related, baseline unrelated), which required 648 trials. A future study may aim to disentangle these components using a distractor condition as a comparison. In such a study, the researcher would be able to look at direct neural correlates of processing of the blinked target picture. Although the N400 component would remain a mystery because a context or prime would be needed for this component, other components of early and late visual processing could be observed. For example, the N2 component, indicative of early orienting of attention, could be observed for the target pictures to determine whether or not there are any differences between correct and incorrect trials or by distractor type for semantically related and unrelated trials. The P300 could also be measured for both the distractor picture and target picture to determine if there are any patterns associated with late

stage processing, and any ERP differences between reported, unreported, or related and unrelated trials could be determined.

Yet another study may accomplish a way to study the N400 to targets that occur during the emotional blink period. Previous attempts have failed to mask primed targets in the emotional blink period, as it appears that strong priming effects enhance target detection making this exceedingly difficult (McKenna 2014). If a study were able to overcome these priming effects and could successfully mask a primed stimuli, direct neural correlates of blinked target pictures could be measured and might shed light on how processing of prime pictures does and does not affect semantic priming of later test pictures.

4.4 Conclusion

This study supports a growing body of evidence that unreported target pictures often do not semantically prime other pictures indicated by the N400 component. A more negative response to unrelated picture stimuli compared to related picture stimuli was found in trials where participants were correct on the semantic relatedness task and therefore were aware of the prime picture. When participants were unable to perform the task and were unaware of the prime, no N400 component was elicited by the test picture regardless of distractor type. I therefore conclude that missed prime pictures do not produce an N400 effect for test pictures.

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